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Report on **Green Mountain Reservoir, Summit County, Colorado**

Prepared July 1977

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For a brief overview of the findings in the lake and its tributaries, see the Survey Publication Report (EPA-600/5-77-004). For more detailed information, see the Appendix. All data collected by the National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

GREEN MOUNTAIN RESERVOIR

SUMMIT COUNTY

COLORADO

EPA REGION VIII

WORKING PAPER NO. 771

WITH THE COOPERATION OF THE

COLORADO DEPARTMENT OF HEALTH

AND THE

COLORADO NATIONAL GUARD

JULY, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Colorado Department of Health for professional involvement, to the Colorado National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

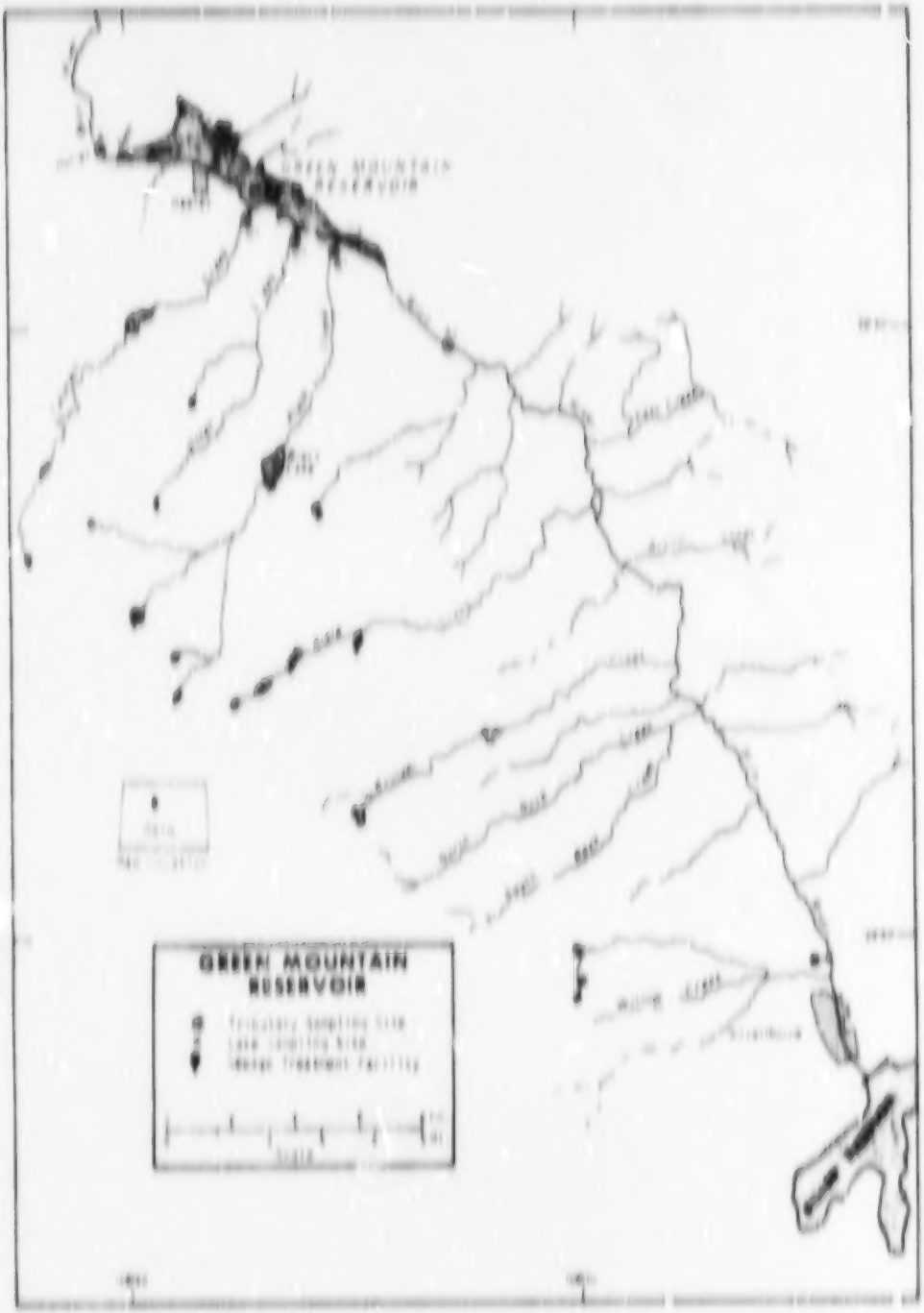
The staff of the Water Quality Control Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Lt. Colonel Paul A. Parsons, the Deputy Adjutant General of Colorado, and Project Officer Colonel Hershel C. Yeargan, who directed the volunteer efforts of the Colorado National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS

STATE OF COLORADO

NAME	COUNTY
Barker	Boulder
Barr	Adams
Blue Mesa	Boulder
Cherry Creek	Arapahoe
Cucharas	Huerfano
Dillon	Summit
Grand	Grand
Green Mountain	Summit
Holbrook	Otero
Meredith	Crowley
Milton	Weld
Navajo	Archuleta, CO; San Juan, Rio Arriba, NM
Shadow Mountain	Grand


GREEN MOUNTAIN RESERVOIR

GREEN MOUNTAIN RESERVOIR

STORET NO. 0808

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Green Mountain Reservoir is oligotrophic. It ranked second in overall trophic quality when the 13 Colorado lakes and reservoirs sampled in 1975 were compared using a combination of six parameters*. One of the water bodies had less median total phosphorus, none had less and one had the same median dissolved orthophosphorus, none had less and six had the same median inorganic nitrogen, five had less mean chlorophyll a, and two had greater mean Secchi disc transparency. No significant depression of dissolved oxygen occurred at depths as great as 39 meters.

Field limnologists did not observe algal concentrations or macrophytes.

B. Rate-Limiting Nutrient:

The results of the algal assay indicate that Green Mountain Reservoir was phosphorus limited at the time the sample was collected (10/09/75). The reservoir data indicate phosphorus limitation in August as well.

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--The phosphorus contribution of point sources amounted to 13.7% of the total load to Green Mountain Reservoir during the sampling year. The nine indirect domestic sources discharging in the upstream Dillon Reservoir drainage* contributed an estimated 8.7%, the Silverthorne Sanitation District wastewater treatment plant added 4.9%, and septic tanks serving shoreline dwellings and a campground accounted for an estimated 0.2% of the total load.

The phosphorus loading of 0.7 g/m^2 measured during the sampling year is less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading but is more than his suggested oligotrophic loading (see page 13). The only significant point source without phosphorus removal during the sampling year was the Frisco Sanitation District (SD) plant which discharged 1,740 kg total P to Dillon Reservoir.

In regard to the Dillon Reservoir point sources, at this time the Summit Cove wastes are treated at the Summit County Phase 0 plant (with phosphorus removal), construction of phosphorus removal facilities at the Frisco SD plant is scheduled to begin in October, 1977, and the Copper Mountain SD is proposing land disposal of plant effluent (Lang, 1977). Allowing for phosphorus retention in that reservoir and assuming 85% removal at the plants and complete removal by land disposal, it is calculated these improvements will reduce the phosphorus load to Green Mountain Reservoir by 395 kg and lower the overall loading to 0.72

* See Working Paper No. 769.

$g/m^2/yr$. Since both reservoirs are phosphorus limited, any reduction of phosphorus inputs would be expected to benefit both water bodies.

2. Non-point sources--The phosphorus contribution of non-point sources, including precipitation, accounted for 86.3% of the total load to Green Mountain Reservoir during the sampling year. The Blue River added 57.9%; Black Creek, 5.7%; Otter Creek, 5.2%; Cataract Creek, 3.1%; and the ungaged minor tributaries and immediate drainage contributed an estimated 12.1% of the total load.

The phosphorus export rate of Otter Creek was appreciably higher than the rates of nearby Black and Cataract creeks (see page 12). The cause of the higher rate is not known, but the mean total phosphorus concentration in Otter Creek was from five to seven times greater than the mean concentrations in the other two streams (see Appendix E).

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS[†]

A. Morphometry[††]:

1. Surface area: 6.60 kilometers^2.

2. Mean depth: 22.2 meters.

3. Maximum depth: 75.3 meters.

4. Volume: 130,758 x 10^6 m^3.

5. Mean hydraulic retention time: 184 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Blue River	1,322.5	9.640
Black Creek	47.9	0.862
Otter Creek	21.8	0.131
Cataract Creek	36.3	0.537
Minor tributaries & immediate drainage -	113.1	2.290
Totals	1,542.8	13.460**

2. Outlet -

Blue River	1,551.4***	13.460

C. Precipitation****:

1. Year of sampling: 30.8 centimeters.

2. Mean annual: 42.6 centimeters.

† Table of metric conversions--Appendix B.
†† At maximum pool level (Nelson, 1955).
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Sum of inflows adjusted to equal outflow.
*** Includes area of reservoir.
**** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Green Mountain Reservoir was sampled two times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the October visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 39.3 meters at station 1, 27.7 meters at station 2, and 7.3 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR [illegible]
STORET CODE [illegible]

PARAMETER	1ST SAMPLING (8/25/75) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (10/ 9/75) 3 SITES RANGE	MEAN	MEDIAN	3D SAMPLING 8 SITES RANGE	MEAN	MEDIAN
TEMP (C)	10.4 - 14.0	13.4	13.6	6.0 - 13.0	10.1	10.7	[illegible]	[illegible]	[illegible]
DISS OXY (MG/L)	5.9 - 7.5	7.0	7.2	7.8 - 9.6	7.6	7.6	[illegible]	[illegible]	[illegible]
CNDCTVY (MICROMO	102. - 134.	117.	120.	1. - 119.	57.	55.	[illegible]	[illegible]	[illegible]
PH (STAND UNITS)	7.5 - 8.7	7.9	7.9	7.7 - 8.4	7.9	7.9	[illegible]	[illegible]	[illegible]
TOT ALK (MG/L	42. - 58.	49.	47.	5. - 73.	34.	35.	[illegible]	[illegible]	[illegible]
TOT P (MG/L)	0.080 - 0.101	0.087	0.084	0.004 - 0.072	0.027	0.011	[illegible]	[illegible]	[illegible]
DISS P (MG/L)	0.057 - 0.067	0.062	0.062	0.032 - 0.051	0.043	0.047	[illegible]	[illegible]	[illegible]
NO2+NO3 (MG/L)	0.071 - 0.128	0.101	0.101	0.028 - 0.055	0.037	0.038	[illegible]	[illegible]	[illegible]
AMMONIA (MG/L)	0.070 - 0.079	0.074	0.076	0.025 - 0.039	0.035	0.035	[illegible]	[illegible]	[illegible]
KJEL N (MG/L)	0.280 - 0.580	0.397	0.382	0.025 - 0.250	0.109	0.080	[illegible]	[illegible]	[illegible]
INORG N (MG/L)	0.340 - 0.540	0.454	0.440	0.042 - 0.091	0.067	0.055	[illegible]	[illegible]	[illegible]
TOTAL N (MG/L)	0.420 - 0.620	0.493	0.480	0.068 - 0.250	0.211	0.238	[illegible]	[illegible]	[illegible]
CHLOPHYL A (UG/L)	7.1 - 8.8	8.3	7.9	3.1 - 4.8	3.9	3.1	[illegible]	[illegible]	[illegible]
SECCHI (METERS)	1.9 - 2.4	2.1	2.0	3.7 - 4.1	3.9	3.5	[illegible]	[illegible]	[illegible]

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
08/25/75	1. Fragilaria sp.	3,470
	2. Cyclotella sp.	132
	3. Asterionella sp.	132
	4. Cryptomonas sp.	88
	Total	3,822
10/09/75	1. Cyclotella sp.	635
	2. Fragilaria sp.	212
	3. Cryptomonas sp.	60
	Total	907

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
08/25/75	1	7.9
	2	7.1
	3	9.8
10/09/75	1	3.1
	2	4.0
	3	3.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.005	0.065	0.1
0.050 P	0.055	0.065	1.7
0.050 P + 1.0 N	0.055	1.065	16.0
1.0 N	0.005	1.065	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity

of Green Mountain Reservoir was low at the time the sample was taken (10/09/75). Also, the significant increase in yield when only phosphorus was added, and the lack of response when only nitrogen was added, indicate phosphorus limitation at that time.

The reservoir data also indicate phosphorus limitation; the mean inorganic nitrogen/orthophosphorus ratios were 28/1 in August and 16/1 in October, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Colorado National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the months of June and July when two or three samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Colorado District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations B-1 and D-1 and multiplying the means by the ZZ area in km^2.

The operator of the Silverthorne Sanitation District wastewater treatment plant provided monthly effluent samples and corresponding flow data. The indirect point-source loads leaving upstream Dillon Reservoir were calculated by multiplying the nutrient loads leaving that reservoir via

* See Working Paper No. 175.

the Blue River (1,060 kg P and 155,490 kg N) by the fractions of the total nutrient loads contributed by the point sources (0.306 for P and 0.075 for N).

A. Waste Sources:

1. Known domestic* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Silverthorne SD	1,000	phosphorus removal	2,211.0	Blue River

2. Indirect domestic - During the sampling year, nine domestic point sources with a combined population equivalence of about 5,330 discharged in the Dillon Reservoir drainage, and a portion of the nutrient loads from those sources reached Green Mountain Reservoir via the Blue River. Phosphorus removal was provided at four of the treatment plants (P.E. ca. 3,750).

3. Industrial - Mining activities in Dillon Reservoir drainage, particularly in the Tenmile Creek watershed, are reported to contribute to elevated levels of molybdenum in that reservoir (Anonymous, 1974). The nutrient significance of the mining operations is not known but is assumed to be minimal.

* Treatment plant questionnaire.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Blue River	3,810	57.9
Black Creek	375	5.7
Otter Creek	345	5.2
Cataract Creek	205	3.1
b. Minor tributaries & immediate drainage (non-point load) -	795	12.1
c. Known municipal STP's -		
Silverthorne SD	325	4.9
Indirect - Dillon Reservoir drainage	570	8.7
d. Septic tanks* -	10	0.2
e. Industrial - Unknown	?	-
f. Direct precipitation** -	150	2.3
Total	6,585	100.0

2. Outputs -

Reservoir outlet - Blue River 6,390

3. Net annual P accumulation - 195 kg.

* Estimate based on 30 shoreline dwellings and one campground; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Blue River	103,755	59.1
Black Creek	10,705	6.1
Otter Creek	2,055	1.2
Cataract Creek	5,600	3.2
b. Minor tributaries & immediate drainage (non-point load) -	21,355	12.2
c. Known municipal STP's -		
Silverthorne SD	10,690	6.1
Indirect - Dillon Reservoir drainage	11,660	6.6
d. Septic tanks* -	355	0.2
e. Industrial - Unknown	?	-
f. Direct precipitation** -	9,285	5.3
Total	175,460	100.0

2. Outputs -

Reservoir outlet - Blue River	168,530

3. Net annual N accumulation - 6,930 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Blue River	1	78
Black Creek	8	221
Otter Creek	16	94
Cataract Creek	6	154

* Estimate based on 30 shoreline dwellings and one campground; see Working Paper No. 175.

** See Working Paper No. 175.

f. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.77	0.02	20.4	0.6

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Green Mountain Reservoir:

"Dangerous" (eutrophic loading)	1.34
"Permissible" (oligotrophic loading)	0.67

V. LITERATURE REVIEWED

Anonymous, 1974. Dillon Reservoir - Blue River study, Colorado, June, July, August - 1973. Tech. Invest. Br., Surv. & Anal. Div., EPA Region VIII, Denver.

Lang, Derald E., 1977. Personal communication (review of preliminary report; status of waste treatment facilities as of July, 1977). CO Dept. of Health, Denver.

Nelson, Wesley C., 1955. Green Mountain Reservoir studies, 1949-1950. CO Dept. of Game & Fish, Denver.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

[illegible]

LAKE CODE	LAKE NAME	[illegible] TOTAL N	[illegible] INDIVIDUAL N	[illegible] [illegible] SEC	[illegible] CHLOPHYA	[illegible] [illegible]	[illegible] [illegible] SECCHI DEPTH	[illegible] [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] RANKED BY INDEX NO.

[illegible]	LAKE CODE	LAKE NAME	[illegible]
1	[illegible]	[illegible]	[illegible]
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10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]

[illegible]

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

[illegible]

[illegible]

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]

| | | |

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

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